



# CEPT Report 48

Report from CEPT to the European Commission in response to the Second Mandate to CEPT on mobile communication services on board aircraft (MCA)

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## 0 EXECUTIVE SUMMARY

This CEPT Report considers the technical impact on ground-based public network of introducing a new Mobile Communication service on board aircraft based on UMTS or LTE technologies operating at height of at least 3000 meter above ground in the 1800 MHz (1710-1785 MHz for the uplink and 1805-1880 MHz for the downlink), in the 2600 MHz (2500 -2570 MHz for uplink and 2620-2690 MHz for downlink) as of LTE and in the 2100 MHz (1920-1980 MHz for uplink and 2110-2170 MHz for downlink) as of UMTS. This report is based on the ECC Report 187 [1].

Emission from mobile terminals on board aircrafts as well as from on board picocells was considered for the following bands (connectivity bands):

- 1920-1980 MHz (uplink) / 2110-2170MHz (downlink)
- 1710-1785 MHz (uplink) / 1805-1880 MHz (downlink)
- 2500-2570 MHz (uplink) / 2620-2690 MHz (downlink).

It is highlighted that, in line with the basic analysis carried out in the ECC Report 187, connectivity in the 2500-2570 / 2620-2690 MHz was found to be incompatible with radar systems in the adjacent band and hence without further analysis it is concluded that this band cannot be made available for connectivity at the present time. Connectivity in the bands 1710-1785 / 1805-1880 MHz for LTE and 1920-1980 / 2110-2170 MHz for UMTS on board aircraft was found to be compatible with ground-based systems.

This CEPT Report concludes on the following additional connectivity bands and associated technical conditions:

### In the 2100 MHz connectivity band (UMTS technology, FDD):

- the transmit power of the UMTS terminal must not exceed -6 dBm/3.84MHz and the maximum number of users should not exceed 20;
- the e.i.r.p. of the ac-UE defined outside the aircraft must not exceed the following values as shown in the table below:

Height above ground (m)	Maximum e.i.r.p, defined outside the aircraft, resulting from the ac-UE in (dBm/3.84 MHz)
3000	3.1
4000	5.6
5000	7
6000	7
7000	7
8000	7

- the transmit power of ac-NodeB must not exceed the maximum e.i.r.p. defined outside the aircraft as provided in the table below:

Height above ground (m)	Maximum e.i.r.p, defined outside the aircraft, resulting from the ac-NodeB (dBm/3.84 MHz)
3000	1.0
4000	3.5
5000	5.4
6000	7.0
7000	8.3
8000	9.5

**In the 1800 MHz connectivity band (LTE technology, FDD):**

- the e.i.r.p. defined outside the aircraft, resulting from the LTE terminal transmitting at 5 dBm/5 MHz inside the aircraft must not exceed the values as provided in the table below:

Height above ground (m)	Maximum e.i.r.p, defined outside the aircraft, resulting from the ac-UE in (dBm/5 MHz)
3000	1.7
4000	3.9
5000	5
6000	5
7000	5
8000	5

- the transmit power of ac-NodeB must not exceed the maximum e.i.r.p. defined outside the aircraft as provided in the table below:

Height above ground (m)	Maximum e.i.r.p, defined outside the aircraft, resulting from the ac-NodeB (dBm/5 MHz)
3000	1.0
4000	3.5
5000	5.5
6000	7.1
7000	8.4
8000	9.6

**Frequency bands controlled by NCU**

With respect to the controlled NCU bands, the studies have shown that there is no change in the power levels defined outside the aircraft for frequency bands at 460 MHz, 900 MHz, 1800 MHz and 2100 MHz as provided in the Commission Decision 2008/294/EC [7].

The e.i.r.p. of the NCU at 2600 MHz must not exceed the maximum e.i.r.p. defined outside the aircraft as provided in the table below:

Height above ground (m)	Maximum e.i.r.p, defined outside the aircraft, resulting from the NCU (dBm/4.75 MHz)
3000	1.9
4000	4.4
5000	6.3
6000	7.9
7000	9.3
8000	10.4

The e.i.r.p. of the NCU at 800 MHz band must not exceed the values as provided in the table below:

Height above ground (m)	Maximum e.i.r.p, defined outside the aircraft, resulting from the NCU (dBm/10 MHz)
3000	-0.87
4000	1.63
5000	3.57
6000	5.15
7000	6.49
8000	7.65

## TABLE OF CONTENTS

<b>0</b>	<b>EXECUTIVE SUMMARY .....</b>	<b>2</b>
<b>1</b>	<b>INTRODUCTION.....</b>	<b>7</b>
<b>2</b>	<b>PART 1 – FEASIBLE MCA TECHNOLOGIES AND RELEVANT FREQUENCY BANDS .....</b>	<b>8</b>
<b>3</b>	<b>PART 2 – COMPATIBILITY STUDIES.....</b>	<b>10</b>
3.1	Background to studies.....	10
3.2	2100 MHz connectivity analysis .....	12
3.2.1	Scenario 1: Impact of g-NodeB on ac-UE .....	12
3.2.2	Scenario 2: Impact of ac-UE on g-NodeB .....	13
3.2.3	Scenario 3: Impact of the NCU on g-UE .....	13
3.2.4	Scenario 4: Impact of the NCU and UMTS connectivity on ground network .....	14
3.2.4.1	<i>Impact of the UMTS connectivity to the ground network .....</i>	<i>14</i>
3.2.4.2	<i>Impact of the NCU on the ground network.....</i>	<i>14</i>
3.2.5	Scenario 5: Impact of the ac_UE on ground based communications (g-UE to g-NodeB) from a single aircraft .....	14
3.2.6	Scenario 6: Impact of the ac_UE on ground based communications (g-UE to g-NodeB) from multiple aircraft .....	15
3.3	1800 MHz connectivity analysis .....	16
3.3.1	Scenario 1: Impact of g-base station on ac-UE.....	16
3.3.2	Scenario 2: Impact of ac-UE on g-base station.....	16
3.3.3	Estimation of the maximum power level emitted by the onboard node B .....	17
3.3.4	Scenario 5: Impact of ac-UE to ground-based network uplink .....	18
3.4	800 MHz NCU analysis .....	18
3.4.1	Scenario 3: Impact of the NCU on g-UE at 800 MHz .....	18
3.4.2	Scenario 4: impact of multiple NCU on g-UE at 800 MHz.....	19
3.5	Protection of adjacent services .....	19
3.5.1	Radio astronomy services in the 2690-2700 MHz.....	19
3.5.2	Radar services operating above 2700 MHz .....	20
<b>4</b>	<b>CONCLUSIONS.....</b>	<b>21</b>
	<b>ANNEX 1: CEPT MANDATE .....</b>	<b>23</b>
	<b>ANNEX 2: LIST OF REFERENCE.....</b>	<b>25</b>

## LIST OF ABBREVIATIONS

<b>Abbreviation</b>	<b>Explanation</b>
<b>ACLR</b>	Adjacent Channel leakage ratio
<b>ac-Node B/BTS</b>	Aircraft base station
<b>ac-UE/MS</b>	Mobile terminal onboard an aircraft
<b>BS</b>	Base Station
<b>e.i.r.p.</b>	equivalent isotropic radiated power
<b>FDD</b>	Frequency division duplex
<b>g-Node B/BTS</b>	Ground base station
<b>g-UE/MS</b>	Ground mobile terminal
<b>GSM</b>	Global System for Mobile communication
<b>GSMOBA</b>	GSM on board aircraft
<b>LTE</b>	Long Term Evolution
<b>MCA</b>	Mobile Communication services on board Aircraft
<b>MCFN</b>	Mobile/ Fixed Communication Network
<b>MCL</b>	Minimum Coupling Loss
<b>NCU</b>	Network Control Unit
<b>PSD</b>	Power Spectral Density
<b>RAS</b>	Radio Astronomy Service
<b>RB</b>	Resource block
<b>SEAMCAT</b>	Spectrum Engineering Advanced Monte-Carlo Analysis Tool
<b>UE</b>	User Equipment
<b>UMTS</b>	Universal Mobile Telecommunications System
<b>WCDMA</b>	Wideband Code Division Multiple Access
<b>WiMAX</b>	Worldwide Interoperability for Microwave Access (IEEE 802.16)

## 1 INTRODUCTION

The European Commission has issued a second Mandate to CEPT on mobile communication services on board aircraft (MCA) to identify the most appropriate technical criteria for the inclusion of new technologies and frequencies in the EC Decision on Mobile Communication Services on Board Aircraft (MCA) (2008/294/EC [7]) to facilitate further deployment of MCA applications in the European Union.

The first Mandate given by the Commission to CEPT on 12 October 2006 on this issue led to CEPT Report 016 [9] being delivered to the Commission on 30 March 2007 (doc. RSCOM07-08) and to a subsequent Commission Decision 2008/294/EC [7] on harmonised conditions of spectrum use for the operation of mobile communication services on aircraft (MCA services) in the European Union, which was adopted by the Commission on 7 April 2008.

The objective of this second Mandate is to study the technical compatibility of airborne UMTS systems, as well as other feasible technologies like LTE or WiMAX, with potentially affected radio services. This Mandate is a follow-up to the first mandate and its purpose is to extend the scope of compatible MCA systems and services currently available.

The Second MCA Mandate comprises the following elements for study:

1. assess specific technical compatibility issues between the operation of airborne UMTS systems and other feasible airborne technologies, such as LTE or WiMAX, in relevant frequency bands, including the terrestrial 2 GHz band (1920-1980 MHz and 2110-2170 MHz), and potentially affected radio services, taking into account the technical conditions developed in CEPT Report 39 [8] for the assessment relating to the terrestrial 2 GHz band;
2. assess the technical compatibility issues between the operation of airborne UMTS systems and other feasible airborne technologies such as LTE or WiMAX in other frequency bands (e.g. the 2.6 GHz band) and identify potentially affected radio services.

In consequence, this CEPT Report is structured in two parts:

- Part 1 addresses the feasible MCA technologies and relevant frequency bands both for the connectivity and NCU parts of the MCA system. The connectivity part provides the network coverage on board, whereas the NCU (Network Control Unit) is designed to ensure that mobile terminals within the cabin cannot access ground-based networks and that they do not transmit any signal without being controlled by the MCA system by raising the noise floor inside the cabin.
- Part 2 covers the various compatibility studies (in-band and adjacent band) which were carried out resulting from the additional technologies and frequency bands for MCA considered under this mandate.

## 2 PART 1 – FEASIBLE MCA TECHNOLOGIES AND RELEVANT FREQUENCY BANDS

Commission Decision 2008/294/EC [7] specifies in Table 1 of the annex GSM in the 1800 MHz band (1710-1785 MHz and 1805-1880 MHz) as the frequency band and system allowed for MCA services (connectivity part of the MCA system). Similarly, Table 2 of the annex GSM lists those frequency bands for which it must be prevented that mobile terminals, receiving within these bands, attempt to register with mobile systems on the ground (NCU part of the MCA system) as follows:

**Table 1: Frequency bands and associated technologies as identified in ECC Report 093**

Frequency band	System on the ground
460-470 MHz	CDMA2000, FlashOFDM
921-960 MHz	GSM <sup>1</sup> , UMTS
1805-1880 MHz	GSM, UMTS
2110-2170 MHz	UMTS

These bands, as well as the associated technical conditions as defined in section 3 of the annex of Commission Decision 2008/294/EC [7], are based on ECC/DEC/(06)07 [2] “on the harmonised use of airborne GSM systems in the frequency bands 1710-1785 and 1805-1880 MHz” and ECC Report 093 [3] “Compatibility between GSM equipment on board aircraft and terrestrial networks” [3].

This CEPT regulatory framework for MCA was revised in 2009 to include the 2.6 GHz band for the NCU part of the MCA system. However, this addition was never transposed in the Commission Decision 2008/294/EC [7].

The first task under the second MCA mandate was therefore to study, based on the above mentioned existing list of bands and technologies, the feasible MCA technologies and frequency bands that should be considered when developing compatibility studies between MCA equipment on board aircraft and terrestrial networks.

The following bands and technologies have been identified during this process for the connectivity part of the MCA system for study:

- GSM1800 (already covered by the current Commission Decision)
- LTE1800 (FDD)
- UMTS2100 (FDD)
- LTE2600 (FDD).

A number of in-band compatibility scenarios have been identified, that need to be studied (see Part 2 of this CEPT Report).

For both the GSM1800 and the LTE1800 MCA system, compatibility with terrestrial GSM and LTE networks in this frequency bands has to be analysed (with the GSM MCA vs. GSM terrestrial case already covered in the current Commission Decision).

Additionally, with the introduction of LTE2600 as a connectivity option for the MCA system, a need was identified to also study the adjacent-band compatibility with the Radioastronomy Service (2690-2700 MHz) and Radars in the 2700-2900 MHz band as potentially affected radio services.

The following table provides a list of all bands and technologies which have been identified during this process for the NCU part of the MCA system including those already identified in the current Commission Decision 2008/294/EC [7]:

<sup>1</sup> Including GSM-R



**Table 2: Updated frequency bands and associated technologies**

Frequency band	System on the ground
460-470 MHz	CDMA2000, FlashOFDM
791-821 MHz	LTE
921-960 MHz	GSM, UMTS, LTE, WiMAX
1805-1880 MHz	GSM, UMTS, LTE, WiMAX
2110-2170 MHz	UMTS, LTE
2620-2690 MHz	UMTS, LTE
2570-2620 MHz	UMTS, LTE, WiMAX

Taking into account the scenarios that have already been studied in ECC Report 093 [3] the following additional scenarios have been studied:

**Table 3: Compatibility scenarios to be considered**

Frequency band	System on the ground
791-821 MHz	LTE
925-960 MHz	LTE, WiMAX
1805-1880 MHz	LTE, WiMAX
2110-2170 MHz	LTE
2620-2690 MHz	LTE
2570-2620 MHz	LTE

These compatibility scenarios are studied in detail within CEPT in the corresponding ECC Report 187 [1]. The scenarios and relevant results are summarised in Part 2 of this CEPT Report.

### 3 PART 2 – COMPATIBILITY STUDIES

#### 3.1 BACKGROUND TO STUDIES

Based on the frequency bands and technologies that have been identified for the connectivity part of the MCA system and systems on ground not yet covered by previous sharing studies responding to the previous mandate, the following scenarios have been identified as described in Table 4 and Table 5 hereafter.

**Table 4: Identifications of sharing studies between onboard connectivity system and ground-based systems**

Band	Technology on board aircraft	In-band sharing with ground-based systems	Adjacent-band sharing with ground-based systems
1800 MHz	GSM	GSM, LTE	
1800 MHz	LTE	GSM, LTE	
2100 MHz FDD	UMTS	UMTS	
2600 MHz FDD 2600 MHz TDD	LTE	LTE RAS (2655-2690 MHz)	Radioastronomy service (RAS) (2690-2700 MHz), Radars (2700-2900 MHz)

**Table 5: Identification of sharing studies between ground-based network and the NCU**

Band	Sharing with ground-based systems	Adjacent-band sharing with ground-based systems
450 MHz	CDMA450, FlashOFDM	
800 MHz	LTE	
900 MHz	GSM, UMTS, LTE, WiMAX	
1800 MHz	GSM, UMTS, LTE, WiMAX	
2100 MHz FDD	UMTS, LTE	
2600 MHz FDD	UMTS, LTE, RAS (2655-2690 MHz)	Radioastronomy service (RAS) (2690-2700 MHz), Radars (2700-2900 MHz)
2600 MHz TDD	UMTS, WiMAX, LTE, RAS (2655-2690 MHz)	

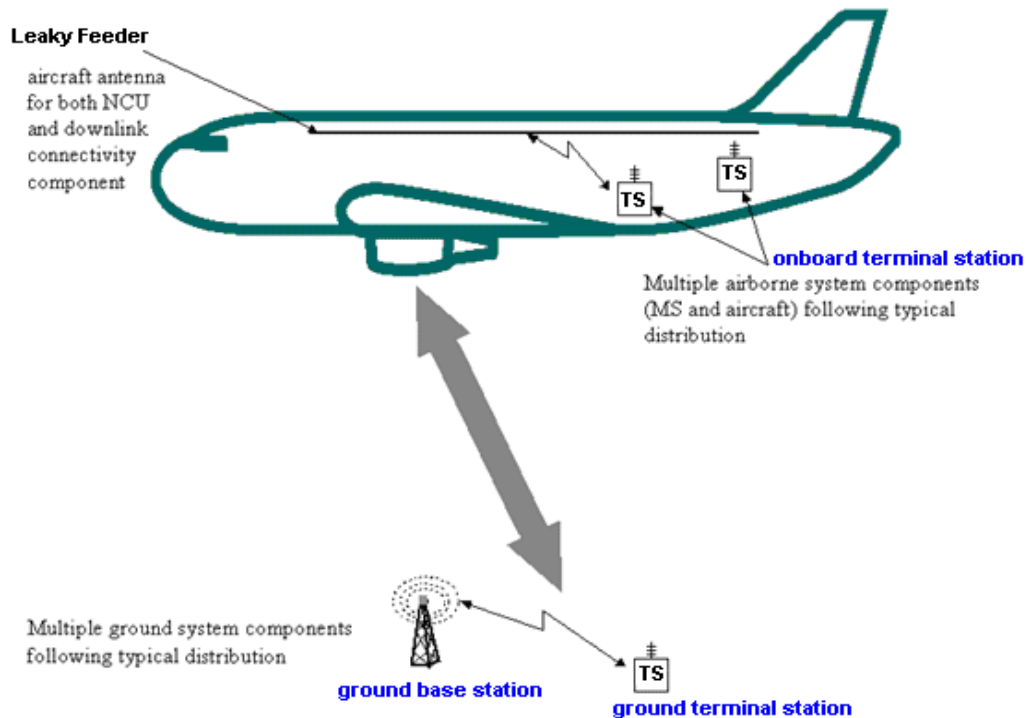
The NCU (Network Control Unit) is a part of the MCA system designed to ensure by raising the noise floor inside the cabin that mobile terminals within the cabin cannot access to the ground-based public networks and that those compatible with the onboard technology do not transmit any signal without being controlled by the MCA system, i.e. the onboard Node B or onboard BTS.

The considered MCA (UMTS / LTE) system is designed to ensure that a mobile terminal on board an aircraft (ac-UE) is unable to communicate with ground-based public mobile networks, whilst providing onboard connectivity to ac-UE in the LTE1800, UMTS2100 or LTE2600 frequency bands.

The new analysis in this report considers the impact of the:

- Network control unit (NCU) emissions to the ground-based downlink (base station transmit → mobile station receive link) (the new bands for control) ;
- Aircraft base station (ac-NodeB) emissions to the ground-based downlink (base station transmit → mobile station receive link), at 1800 MHz (LTE) 2100 MHz (UMTS) and 2600 MHz (LTE) only;

- Mobile terminal on aircraft (ac-UE) emissions to the ground-based uplink (mobile station transmit → base station receive link), at 1800 MHz (LTE), 2100 MHz (UMTS) and 2600 MHz (LTE).



**Figure 1: MCA and ground-based cellular system interference scenario**

The following six scenarios have been studied when needed:

- Scenario 1: Impact of ground base station (g-NodeB) to the ac-UE. This scenario, using a minimum coupling loss (MCL) approach, identifies the conditions in which the mobile terminal on aircraft (ac-UE) will have visibility of the ground-based networks. Note that the NCU and aircraft base station (ac-NodeB) are not taken into account in this scenario.
- Scenario 2: Impact of the ac-UE to g-NodeB. This scenario, using both MCL approach and SEAMCAT analysis, assessed in which conditions the ac-UE will have the ability to connect to ground-based networks, and in that case, the impact on other ground-based links. Note that the NCU and ac-NodeB are not taken into account in this scenario.
- Scenarios 3 and 4: Impact of onboard NCU and ac-NodeB emissions to the downlink of ground-based networks, for single (Scenario 3) and multiple (Scenario 4) aircraft respectively;
- Scenarios 5 and 6: Impact of ac-UE emissions to the uplink of ground-based networks, for single (Scenario 5) and multiple (Scenario 6) aircraft respectively.

**Table 6: Modelling scenarios**

Scenario #	Interferers	Interfered system
1	g-NodeB	ac-UE
2	ac-UE	g-NodeB
3	NCU and ac-NodeB	Ground-based network downlink
4	Multiple aircraft NCU and ac-NodeB	Ground-based network downlink
5	ac-UE	Ground-based network uplink
6	Multiple aircraft ac-UE	Ground-based network uplink

ECC Report 093 [3] considers the technical compatibility between GSM equipment on board aircraft and ground-based public mobile networks. The additional compatibility studies performed here address the impact on ground-based public mobile networks of introducing a MCA system based on the UMTS / LTE technology operating at a height of at least 3000 metres above ground level in the following frequency bands:

- 1710-1785 MHz for uplink (terminal transmit, base station receive) / 1805-1880 MHz for downlink (base station transmit, terminal receive);
- 1920-1980 MHz for uplink (terminal transmit, base station receive) / 2110-2170 MHz for downlink (base station transmit, terminal receive);
- 2500-2570 MHz for uplink (terminal transmit, base station receive) / 2620–2690 MHz for downlink (base station transmit, terminal receive).

### 3.2 2100 MHz CONNECTIVITY ANALYSIS

#### 3.2.1 Scenario 1: Impact of g-NodeB on ac-UE

This scenario assesses in which conditions the ac-UE will have visibility of the terrestrial networks, by using MCL calculations. For the purposes of this new EC mandate, it was only necessary to repeat Scenario 1 to identify the impact of 2100 MHz LTE g-NodeB systems on ac-UE.

From the calculation for different elevation angles, the worst case elevation angle considered for the study at 2100 MHz is 48° whatever the height above ground of the aircraft. The relative antenna gain is -1.84 dBi

**Table 7: Impact of g-NodeB on ac-UE at 2100 MHz**

Height above ground (m)	Worst case elevation angle (deg)	Distance aircraft / base station (km)	Path loss (dB)	Antenna gain (dBi)	LTE2100		
					e.i.r.p. (dBm)	Max. received power in aircraft, $P_{\text{max\_rec:ac-MS}}$ (dBm/ch)	Margin(dB)
3000	48	4.04	111.2	-1.84	44.16	-72.0	-25.0
4000	48	5.38	113.7	-1.84	44.16	-74.5	-22.5
5000	48	6.73	115.6	-1.84	44.16	-76.4	-20.6
6000	48	8.07	117.2	-1.84	44.16	-78.0	-19.0
7000	48	9.42	118.5	-1.84	44.16	-79.4	-17.6
8000	48	10.76	119.7	-1.84	44.16	-80.5	-16.5
9000	48	12.1	120.7	-1.84	44.16	-81.5	-15.5
10000	48	13.45	121.6	-1.84	44.16	-82.5	-14.5

A negative margin means that an extra isolation is necessary to remove the visibility of the ground networks.

**3.2.2 Scenario 2: Impact of ac-UE on g-NodeB**

This scenario assesses in which conditions the onboard ac-UE will have the ability to connect to terrestrial networks.

**Table 8: impact of ac-UE on g-NodeB at 2100 MHz**

Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance aircraft / g_UE (km)	Path loss (dB)	Rx Ant. Gain (dBi) at given angle	LTE2100		
					e.i.r.p. (dBm)	Max. received power on ground, $P_{max\_rec:g\_nodeB}$ (dBm/ch)	Margin(dB)
3000	48	4.04	111.2	-1.84	23	-95.0	-6.5
4000	48	5.38	113.7	-1.84	23	-97.5	-4.0
5000	48	6.73	115.6	-1.84	23	-99.4	-2.1
6000	48	8.07	117.2	-1.84	23	-101.0	-0.5
7000	48	9.42	118.5	-1.84	23	-102.4	0.9
8000	48	10.76	119.7	-1.84	23	-103.5	2.0
9000	48	12.10	120.7	-1.84	23	-104.5	3.0
10000	48	13.45	121.6	-1.84	23	-105.5	4.0

A negative margin shows that it is possible that an UE could connect to a ground-based mobile network

**3.2.3 Scenario 3: Impact of the NCU on g-UE**

In this frequency band, the ECC/DEC/(06)07 [2] provides the maximum e.i.r.p. defined outside the aircraft. At the first stage, the minimum value needed to screen the LTE ground network should be defined and calculate what the increase of noise floor will be.

**Table 9: MCL result of impact of the NCU on g-UE**

Height above ground (km) ⇒	3	4	5	6	7	8	9	10
Max received Signal Level (dBm/channel) inside aircraft	-72.0	-74.5	-76.4	-78.0	-79.4	-80.5	-81.5	-82.5
Radiation Factor (Large Aircraft) (dB)	71	71	71	71	71	71	71	71
Aircraft Attenuation for leaky feeder transmission (dB)	10	10	10	10	10	10	10	10
Equivalent e.i.r.p. (as point of source) (dBm/channel)	-11.0	-13.5	-15.4	-17.0	-18.4	-19.5	-20.5	-21.5
Free Space Propagation Losses (dB)	108.6	111.1	113.0	114.6	116.0	117.1	118.1	119.0
Maximum Received Noise by g-UE (dBm)	-119.6	-124.6	-128.5	-131.6	-134.3	-136.6	-138.7	-140.5
System Noise Level, reference values (dB/channel)	-95	-95	-95	-95	-95	-95	-95	-95
Increase of the noise floor at g-UE with respect to reference values (dB)	0.015	0.005	0.002	0.001	0.001	0.000	0.000	0.000
Equivalent e.i.r.p. (as point of source) (dBm/ 200 kHz)	-28.01	-30.49	-32.44	-34.02	-35.36	-36.51	-37.53	-38.45

The above table shows that the increase of noise floor at ground UE remains below 1 dB. It also shows that the value needed to screen the ground LTE2100 cellular network is below the e.i.r.p. limit defined in the ECC/DEC/(06)07 [2].

Instead of performing all the SEAMCAT simulations starting from the result contained in Table 9 above, it was proposed to use the e.i.r.p. limit as contained in the ECC/DEC/(06)07 [2] and to perform only the scenario 4 in which several interferers will be taken into account.

**3.2.4 Scenario 4: Impact of the NCU and UMTS connectivity on ground network**

The e.i.r.p. used is the one as defined in the ECC/DEC/(06)07 [2] at 3000 m.

*3.2.4.1 Impact of the UMTS connectivity to the ground network*

Table 10 below provides the impact of UMTS connectivity system onboard aircraft to the ground network.

**Table 10: Simulation result for scenario 4**

Description of the case		Reference cell	CDMA system
		Average capacity loss	Average capacity loss
Multiple ac-BTS to terrestrial UMTS network	Normal day (4 interferers)	0%	3.72%
Multiple ac-BTS to terrestrial UMTS network	Busy day (8 interferers)	0 %	2.35%

*3.2.4.2 Impact of the NCU on the ground network*

Table 11 below provides the impact of the NCU to the ground LTE network.

**Table 11: Simulation result for scenario 4**

Description of the case		Reference cell		OFDMA system	
		Average capacity loss	Average bitrate loss	Average capacity loss	Average bitrate loss
Multiple NCU to terrestrial LTE network	Normal day (18 interferers)	0%	0.005%	0 %	0.003 %
Multiple NCU to terrestrial LTE network	Extreme busy day (33 interferers)	0 %	0.009%	0%	0.005%

**3.2.5 Scenario 5: Impact of the ac\_UE on ground based communications (g-UE to g-NodeB) from a single aircraft**

In this scenario the impact of the ac-UE (single aircraft) on the terrestrial UMTS networks on the uplink communications link between the g-UE to the g-BTS was studied.

The results in Table 12 below identify that the protection threshold for ground based systems (single aircraft) is met assuming a maximum number of simultaneous users of 20 transmitting at -6 dBm.

**Table 12: Simulation results with number of simultaneous ac\_UE=20**

Height above ground (m)	Average Capacity Loss	
	e.i.r.p. ac-UE= -6dBm	
	Reference cell	CDMA system
3000	3.74%	0.00%
5000	0.03%	0.00%
8000	0.03%	0.00%

### 3.2.6 Scenario 6: Impact of the ac\_UE on ground based communications (g-UE to g-NodeB) from multiple aircraft

In this scenario the impact of the ac-UE (multiple aircrafts) on the terrestrial UMTS networks on the uplink communications link between the g-UE to the g-BTS was studied.

The results in the table below identify that the protection threshold for ground based systems (multiple aircrafts) is met assuming a maximum number of simultaneous users of 20 transmitting at -6 dBm.

**Table 13: Simulation results with number of simultaneous ac\_UE=20**

Description of the case		Average Capacity Loss	
		e.i.r.p. ac-UE= -6dBm	
		Reference cell	CDMA system
Multiple ac_UE to terrestrial UMTS network	Normal day	0.22%	0 %
Multiple ac_UE to terrestrial UMTS network	Busy day	0 .38%	0%

The results in the above table identify that the protection threshold for ground based systems (multiple aircraft) is met assuming a maximum number of simultaneous users of 20 transmitting at -6dBm.

The following results in the table below show that the average capacity loss remains below 5%.

**Table 14: MCL simulation results**

Height above ground (m)	MCL, 1 dB increased noise floor				Effective attenuation (dB)	Max permitted e.i.r.p. (dBm/channel)
	Aircraft attenuation (dB)	Ac-UE power (dBm)	Multiple user factor (dB)	Required attenuation (dB)		
3000	5	-6	13	-1.1	3.9	3.1
4000	5	-6	13	-3.6	1.4	5.6
5000	5	-6	13	-5.5	0	7
6000	5	-6	13	-7.1	0	7
7000	5	-6	13	-8.5	0	7
8000	5	-6	13	-9.6	0	7

### 3.3 1800 MHz CONNECTIVITY ANALYSIS

#### 3.3.1 Scenario 1: Impact of g-base station on ac-UE

This scenario assesses in which conditions the ac-UE will have visibility of the terrestrial LTE1800 networks, by using MCL calculations because ECC Report 093 [3] -in all cases - shows MCL calculations to represent the worst case scenario. Therefore, there was no requirement for further statistical analysis.

The worst case elevation angle is 48 °, corresponding to an antenna gain of -1.84 dBi.

**Table 15: Impact of g-LTE base station on ac-UE at 1800 MHz**

Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance aircraft / base station (km)	Path loss (dB)	Ant. Gain (dBi) at given angle	LTE1800		
					e.i.r.p. (dBm)	Max. received power in aircraft, $P_{max\ rec:ac-MS}$ (dBm/ch)	Margin (dB)
3000	48	4.04	109.9	-1.84	41.16	-73.7	-26.3
4000	48	5.38	112.4	-1.84	41.16	-76.2	-23.8
5000	48	6.73	114.3	-1.84	41.16	-78.1	-21.9
6000	48	8.07	115.9	-1.84	41.16	-79.7	-20.3
7000	48	9.42	117.2	-1.84	41.16	-81.1	-18.9
8000	48	10.76	118.4	-1.84	41.16	-82.2	-17.8
9000	48	12.1	119.4	-1.84	41.16	-83.2	-16.8
10000	48	13.45	120.3	-1.84	41.16	-84.2	-15.8

A negative margin means that an extra isolation is necessary to remove the visibility of the ground networks.

#### 3.3.2 Scenario 2: Impact of ac-UE on g-base station

This scenario assesses in which conditions the onboard ac-UE will have the ability to connect to terrestrial networks.

**Table 16: impact of ac-UE on g-base station at 1800 MHz**

Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance aircraft / g_UE (km)	Path loss (dB)	Rx Ant. Gain (dBi) at given angle	LTE1800		
					UE e.i.r.p. (dBm)	Max. received power on ground, $P_{max\ rec: g\_nodeB}$ (dBm/ch)	Margin (dB)
3000	48	4.04	109.9	-1.84	23	-93.7	-7.8
4000	48	5.38	112.4	-1.84	23	-96.2	-5.3
5000	48	6.73	114.3	-1.84	23	-98.1	-3.4
6000	48	8.07	115.9	-1.84	23	-99.7	-1.8
7000	48	9.42	117.2	-1.84	23	-101.1	-0.4
8000	48	10.76	118.4	-1.84	23	-102.2	0.7
9000	48	12.1	119.4	-1.84	23	-103.2	1.7
10000	48	13.45	120.3	-1.84	23	-104.2	2.7

A negative margin shows that it is possible that an UE could connect to a ground-based mobile network.



### 3.3.3 Estimation of the maximum power level emitted by the onboard node B

Based on the ECC/DEC/(06)07 [2] and taken into account the fact that the GSM mobile terminal will transmit 0 dBm, then it is possible to determine the minimum aircraft attenuation as shown in Table 17.

**Table 17: Aircraft attenuation**

Height above ground (m)	Aircraft attenuation (dB)
3000	3.3
4000	1.1
5000	-0.5
6000	-1.8
7000	-2.9
8000	-3.8

From Table 17, it is possible to estimate the e.i.r.p. outside the aircraft with the following formula:

e.i.r.p. (dBm/Channel)= Max received signal + Radiation factor – aircraft attenuation + 5 dB (this value was used as initial assumption in the ECC Report 093 [3]).

Then, from the calculated e.i.r.p., the increase of noise level will be estimated.

**Table 18: MCL calculation**

Height above ground (m) ⇒	3000	4000	5000	6000	7000	8000
Max received signal level (dBm/5MHz)	-73.7	-76.2	-78.1	-79.7	-81.1	-82.2
Radiation Factor (Large Aircraft) (dB)	70	70	70	70	70	70
Aircraft Attenuation (dB)	3.3	1.1	-0.5	-1.8	-2.9	-3.8
Equivalent e.i.r.p. (as point of source) (dBm/5MHz)	-1.0	-1.3	-1.6	-1.9	-2.2	-2.4
Free Space Propagation Losses (dB)	107.3	109.8	111.7	113.3	114.6	115.8
Maximum Received Noise by g-MS (dBm)	-108.3	-111.1	-113.4	-115.2	-116.8	-118.2
System Noise Level, reference values (dB/bw)	-100	-100	-100	-100	-100	-100
Increase of the noise floor at g-MS with respect to reference values (dB)	0.60	0.33	0.20	0.13	0.09	0.06

From Table 18, it is then possible to calculate the required attenuation in order to get the 1 dB increase noise floor at the ground UE:

**Table 19: Calculation of maximum e.i.r.p.**

Height above ground (km)	MCL, 1 dB increased noise floor			Maximum e.i.r.p. produced by the ac-nodeB (dBm/5 MHz)	Maximum e.i.r.p. produced by the ac-nodeB (dBm/200 kHz)
	MS attenuation (dB)	Ac-nodeB power (dBm)	Required attenuation (dB)		
3	3.3	-1	-2.43	1.43	-12.55
4	1.1	-1.3	-5.22	3.92	-10.06
5	-0.5	-1.6	-7.50	5.9	-8.08
6	-1.8	-1.9	-9.36	7.46	-6.52
7	-2.9	-2.2	-10.94	8.74	-5.24
8	-3.8	-2.4	-12.36	9.96	-4.02

Based on the result of the maximum e.i.r.p., defined outside the aircraft and produced by the ac-NodeB in 1800 MHz, it can be seen that the limit contained in the ECC/DEC/(06)07 [2] in the band 1800 MHz remains.

**3.3.4 Scenario 5: Impact of ac-UE to ground-based network uplink**

**Table 20: MCL calculation for ac-UE1800 MHz to terrestrial LTE networks**

Height above ground (km) ⇒	3	4	5	6	7	8	9	10
Distance g-nodeB/ ac-UE (km)	4.04	5.38	6.73	8.07	9.42	10.76	12.1	13.45
UE power level (dBm/5 MHz)	5	5	5	5	5	5	5	5
Aircraft Attenuation (dB)	3.3	1.1	0	0	0	0	0	0
e.i.r.p. outside the aircraft (dBm/5 MHz)	1.7	3.9	5	5	5	5	5	5
Free Space Propagation Losses (dB)	109.4	111.9	113.8	115.4	116.7	117.9	118.9	119.8
Terrestrial LTE antenna Gain (dBi)	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8
Maximum Received Noise by g-MS (dBm/5 MHz)	-109.5	-109.8	-110.6	-112.2	-113.5	-114.7	-115.7	-116.6
System Noise Level, reference values (dBm/5 MHz)	-102	-102	-102	-102	-102	-102	-102	-102
Increase of the noise floor at g-MS with respect to reference values (dB)	0.71	0.67	0.56	0.40	0.30	0.23	0.18	0.15

The table above shows that the increase of noise remains below 1 dB.

**3.4 800 MHz NCU ANALYSIS**

**3.4.1 Scenario 3: Impact of the NCU on g-UE at 800 MHz**

This scenario assesses the impact of onboard NCU emissions on the ground-based UE receivers, by using MCL calculations.

**Table 21: Impact of a signal NCU to terrestrial LTE network**

Height above ground (km)	3	4	5	6	7	8	9	10
Max received Signal Level (dBm/channel) inside aircraft	-58.92	-61.44	-63.34	-64.94	-66.24	-67.44	-68.44	-69.34
Radiation Factor (Large Aircraft) (dB)	64	64	64	64	64	64	64	64
Aircraft Attenuation for leaky feeder transmission (dB)	10	10	10	10	10	10	10	10
Equivalent e.i.r.p. (as point of source) (dBm/10 MHz)	-4.92	-7.44	-9.34	-10.94	-12.24	-13.44	-14.44	-15.34
Free Space Propagation Losses (dB)	100.00	102.50	104.44	106.02	107.36	108.52	109.55	110.46
Maximum Received Noise by g-UE (dBm/channel)	-104.92	-109.94	-113.78	-116.96	-119.60	-121.96	-123.99	-125.80
System Noise Level, reference values (dBm/channel)	-95	-95	-95	-95	-95	-95	-95	-95
Increase of the noise floor at g-UE with respect to reference values (dB)	0.42	0.14	0.06	0.03	0.02	0.01	0.01	0.00

From the results of Table 21, it is then possible to calculate, for different height above ground of the aircraft what the equivalent e.i.r.p. of the NCU should be to get 1 dB increase of noise floor at ground UE. These values are contained in Table 22.

**Table 22: Maximum e.i.r.p. of the NCU**

Height above ground (km)	3	4	5	6	7	8	9	10
Equivalent e.i.r.p. (dBm/10 MHz)	-0.87	1.63	3.57	5.15	6.49	7.65	8.68	9.59

The Table 23 below provides the results of SEAMCAT simulations for average capacity loss

**Table 23: Average capacity loss**

Situation		Reference Cell		OFDMA System	
Description of the case		Average capacity loss	Average bitrate loss	Average capacity loss	Average bitrate loss
NCU transmitting in the 800 MHz band over terrestrial LTE networks	Transmitter placed randomly within a radius of 17 km at 3 km above ground	0 %	0.001 %	0 %	0 %
	Transmitter placed randomly within a radius of 28 km at 5 km above ground	0 %	0.02 %	0 %	0.001 %
	Transmitter placed randomly within a radius of 45 km at 8 km above ground	0 %	0.002 %	0 %	0.001 %
	Transmitter placed randomly within a radius of 56 km at 10 km above ground	0 %	0.002 %	0 %	0.001 %

### 3.4.2 Scenario 4: impact of multiple NCU on g-UE at 800 MHz

Table 24 provides the result for the scenario 4.

**Table 24: Simulation result for scenario 4**

Description of the case		Reference cell		OFDMA system	
		Average capacity loss	Average bitrate loss	Average capacity loss	Average bitrate loss
Multiple NCU to terrestrial LTE network	Normal day (18 interferers)	0%	0.006%	0 %	0.003 %
Multiple NCU to terrestrial LTE network	Extreme busy day (33 interferers)	0%	0.01%	0 %	0.004 %

The result shows that the average capacity loss remains below 1%.

## 3.5 PROTECTION OF ADJACENT SERVICES

### 3.5.1 Radio astronomy services in the 2690-2700 MHz

For the bands in question, the appropriate threshold of interference level of spectral power flux density taken from Table 1 of Recommendation ITU-R RA.769-2 [5] (continuum observations) is -247 dB(W/m<sup>2</sup>.Hz), which equates to a maximum interference power level in a notional 10 MHz bandwidth of -177 dBm. This threshold of interference level is also based on an assumed observational integration time of 2000 s. Continuum observations made with single-dish telescopes commonly undertaken in European observatories are well characterised by these parameters.

Assuming the aircraft is in line of sight of an observatory, at these frequencies the path loss 'L' may be calculated to a reasonable approximation based on the free space path loss equation (i.e. For 3000 m Height above ground at 2695 MHz, L = 110.6 dB). For the scenario stated, the power 'P<sub>ext</sub>' outside the aircraft at 3000 m falling into the band must therefore be less than:

$$P_{\text{ext}} = -177 + 110.6 = -66.4 \text{ dBm/10 MHz}$$

### 3.5.2 Radar services operating above 2700 MHz

The impact of MCA system operating in 2500-2690 MHz band on radar system above 2700 MHz band was assessed. This analysis assumes radar performance parameters identical to ECC Report 174 [4]. Table 25 and Table 26 present the results of the compatibility studies with adjacent band radar services.

**Table 25: Power Spectral Density at victim receiver (radar) from 3000 m to 10000 m and (I+N)/N**

Aircraft height (m)	Free Space Path Loss (from onboard equipment to victim receiver) (dB)	Power received by the radar $P_{v-Rx}$ (dBm/MHz)	Increase in noise level (I+N)/N (dB)	Power received by the radar $P_{v-Rx}$ (dBm/MHz)	Increase in noise level (I+N)/N (dB)
		Type 1		Type 2 and 3	
3000	110.36	-141.3	0.051	-147.3	0.013
4000	112.86	-143.8	0.029	-149.8	0.007
5000	114.80	-145.7	0.018	-151.7	0.005
6000	116.38	-147.3	0.013	-153.3	0.003
7000	117.72	-148.6	0.009	-154.6	0.002
8000	118.88	-149.8	0.007	-155.8	0.002
9000	119.90	-150.8	0.006	-156.8	0.001
10000	120.82	-151.7	0.004	-157.7	0.001

With respect to the radar type 4, the worst case is when the aircraft is at 37° elevation angle from the radar, and the elevation angle of the radar antenna is at 37°.

**Table 26: Power Spectral Density at victim receiver (radar) from 3000 m to 10000 m and (I+N)/N for radar type 4**

Aircraft height (m)	Free Space Path Loss (from onboard equipment to radar) (dB)	Power received by the radar $P_{v-Rx}$ (dBm/MHz)	Increase in noise level (I+N)/N (dB)
3000	114.81	-128.68	0.84
4000	117.31	-131.18	0.50
5000	119.25	-133.12	0.32
6000	120.83	-134.70	0.23
7000	122.17	-136.04	0.17
8000	123.33	-182.19	0.00
9000	124.35	-138.22	0.10
10000	125.26	-139.13	0.08

From the protection criteria for Radar I/N = -10dB (Recommendation ITU-R M.1464-1) [6] it is derived the criterion (I+N)/N = 0.41dB. The results in Table 26 indicate that the increase in noise floor at the victim receiver is exceeding the protection level for Radar type 4, i.e. > 0.41dB, whereas the other type of radars are compliant with the protection level.

Based on the basic analysis carried out, compatibility with adjacent band radar services could not be ensured, therefore without further analysis at this present time it is concluded that this band could not be made available for connectivity.

## 4 CONCLUSIONS

This CEPT Report based on the ECC Report 187 [1], described additional studies on the compatibility of a MCA system with terrestrial networks, when the aircraft is at least 3000 m above ground. The studies demonstrated that harmful interference to terrestrial networks will not occur provided that the following technical conditions are met:

### In the 2100 MHz connectivity band (UMTS technology, FDD):

- the transmit power of the UMTS terminal must not exceed -6 dBm/3.84MHz and the maximum number of users should not exceed 20;
- the e.i.r.p. of the ac-UE defined outside the aircraft must not exceed the following values as shown in the table below:

Height above ground (m)	Maximum e.i.r.p, defined outside the aircraft, resulting from the ac-UE in (dBm/3.84 MHz)
3000	3.1
4000	5.6
5000	7
6000	7
7000	7
8000	7

- the transmit power of ac-NodeB must not exceed the maximum e.i.r.p. defined outside the aircraft as provided in the table below:

Height above ground (m)	Maximum e.i.r.p, defined outside the aircraft, resulting from the ac-NodeB (dBm/3.84 MHz)
3000	1.0
4000	3.5
5000	5.4
6000	7.0
7000	8.3
8000	9.5

### In the 1800 MHz connectivity band (LTE technology, FDD):

- the e.i.r.p. defined outside the aircraft, resulting from the LTE terminal transmitting at 5 dBm/5 MHz inside the aircraft must not exceed the values as provided in the table below:

Height above ground (m)	Maximum e.i.r.p, defined outside the aircraft, resulting from the ac-UE in (dBm/5 MHz)
3000	1.7
4000	3.9
5000	5
6000	5
7000	5
8000	5

- the transmit power of ac-NodeB must not exceed the maximum e.i.r.p. defined outside the aircraft as provided in the table below:

Height above ground (m)	Maximum e.i.r.p, defined outside the aircraft, resulting from the ac-NodeB (dBm/5 MHz)
3000	1.0
4000	3.5
5000	5.5
6000	7.1
7000	8.4
8000	9.6

**In the 2600 MHz connectivity band (LTE technology, FDD)**

Compatibility with the adjacent band Radio astronomy service primary allocation at 2690-2700 MHz can be achieved assuming that the out-of-band emission outside the aircraft is lower than – 66.4 dBm/10 MHz at 3000 metres. To achieve compatibility with the RAS secondary allocation in the shared band at 2655-2690 MHz would require the same limit on emissions.

It was found that in the 2600 MHz connectivity band, based on the basic analysis carried out in this report that compatibility with adjacent band radar services could not be ensured. Therefore without further analysis it is concluded that this band cannot be made available for connectivity.

**Frequency bands controlled by NCU**

With respect to the controlled NCU bands, the studies have shown that there is no change in the power levels defined outside the aircraft for the frequency bands at 460 MHz, 900 MHz, 1800 MHz and 2100 MHz as provided in the Commission Decision 2008/294/EC [7].

The e.i.r.p. of the NCU at 2600 MHz must not exceed the maximum e.i.r.p. defined outside the aircraft as provided in the table below:

Height above ground (m)	Maximum e.i.r.p, defined outside the aircraft, resulting from the NCU (dBm/4.75 MHz)
3000	1.9
4000	4.4
5000	6.3
6000	7.9
7000	9.3
8000	10.4

The e.i.r.p. of the NCU at 800 MHz band must not exceed the values as provided in the table below:

Height above ground (m)	Maximum e.i.r.p, defined outside the aircraft, resulting from the NCU (dBm/10 MHz)
3000	-0.87
4000	1.63
5000	3.57
6000	5.15
7000	6.49
8000	7.65

**ANNEX 1: CEPT MANDATE**

**EUROPEAN COMMISSION**  
 Information Society and Media Directorate-General  
 Electronic Communications Policy  
**Radio Spectrum Policy**

Brussels, 05 October 2011  
 DG INFSO/B4

**ADOPTED**

**SECOND MANDATE TO CEPT  
 TO UNDERTAKE TECHNICAL STUDIES ON MOBILE COMMUNICATION SERVICES ON BOARD  
 AIRCRAFT (MCA)**

**PURPOSE**

Pursuant to Art. 4 of the Radio Spectrum Decision 676/2002/EC<sup>2</sup>, CEPT is mandated to undertake the work required to identify the most appropriate technical criteria for the inclusion of new technologies and frequencies in the EC Decision on Mobile Communication Services on Board Aircraft (MCA) (2008/294/EC) to facilitate further deployment of MCA applications in the European Union.

The objective of this Mandate is to study the technical compatibility of airborne UMTS systems, as well as other feasible technologies like LTE or WiMax, with potentially affected radio services. This Mandate is a follow-up to the first EC Mandate on MCA of 12 October 2006, and its purpose is to extend the scope of compatible MCA systems and services currently available.

In the European Union, the airworthiness of airborne mobile communication systems in terms of avoiding the creation of harmful interference to aviation systems is the competence of the European Aviation Safety Agency (EASA), and therefore does not fall into the scope of this Mandate. The avoidance of harmful interference which would endanger the functioning of aviation-related safety services takes priority over any other issue.

**JUSTIFICATION**

The first Mandate given by the Commission to CEPT on 12 October 2006 on this issue led to a final CEPT Report being delivered to the Commission on 30 March 2007 (doc. RSCOM07-08) and to a subsequent Commission Decision 2008/294/EC on harmonised conditions of spectrum use for the operation of mobile communication services on aircraft (MCA services) in the European Union, which was adopted by the Commission on 7 April 2008.

<sup>2</sup> Decision 676/2002/EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community, OJ L 108 of 24.4.2002, p.1.

Allowing people to be connected everywhere at all time is a recurring theme of the policy on the Information Society and of the i2010 initiative. The development of increased means of communicating is likely to be beneficial for work productivity and for growth in the mobile telephony market, for the fulfilment of the Digital Agenda for Europe, and must be in line with the principles of service and technology neutrality as defined in the regulatory framework for electronic communications. Airborne connectivity applications are being used mostly for cross-border flights within the European Union, as well as for flights departing from and arriving in the European Union, and are pan-European in nature. The inclusion of new appropriate technologies and frequencies for the use of MCA services would therefore further support the objectives of the EU Single Market.

**ORDER AND SCHEDULE**

CEPT is hereby mandated to undertake all required activities to

- (1) assess specific technical compatibility issues between the operation of airborne UMTS systems and other feasible airborne technologies, such as LTE or WiMax, in relevant frequency bands, including the terrestrial 2 GHz band (1920-1980 MHz and 2110-2170 MHz), and potentially affected radio services, taking into account the technical conditions developed in CEPT Report 39 for the assessment relating to the terrestrial 2 GHz band;
- (2) assess the technical compatibility issues between the operation of airborne UMTS systems and other feasible airborne technologies such as LTE or WiMax in other frequency bands (e.g. the 2.6 GHz band) and identify potentially affected radio services.

CEPT shall undertake this work in full awareness of and close collaboration with developments regarding the airworthiness certification of these systems by aviation safety authorities.

CEPT should provide deliverables according to the following schedule:

<b>Delivery date</b>	<b>Deliverable</b>	<b>Subject</b>
20 June 2012	Interim Report from CEPT to the Commission	Description of work undertaken and interim results under this Mandate.
21 November 2012*	Final Report from CEPT to the Commission	Description of work undertaken and final results under this Mandate
6 March 2013	Final Report from CEPT to the Commission, taking into account the outcome of the public consultation	

\* subject to subsequent public consultation

In addition, CEPT is requested to report on the progress of its work pursuant to this Mandate to all the meetings of the Radio Spectrum Committee taking place during the course of the Mandate.

The result of this Mandate can be made applicable in the European Union pursuant to Article 4 of the Radio Spectrum Decision.

In implementing this Mandate, the CEPT shall take the utmost account of EU law applicable.



**ANNEX 2: LIST OF REFERENCE**

- [1] ECC Report 187 on compatibility study between mobile communication services on board aircraft (MCA) and ground-based systems.
- [2] ECC Decision (06)07 on the harmonised use of airborne GSM systems in the frequency bands 1710-1785 and 1805-1880 MHz.
- [3] ECC Report 093 "compatibility between GSM equipment on board aircraft and terrestrial networks"
- [4] ECC Report 174 "Compatibility between the mobile service in the band 2500-2690 MHz and the radiodetermination service in the band 2700-2900 MHz".
- [5] Recommendation ITU-R RA.769-2 "Protection criteria used for radio astronomical measurements "
- [6] Recommendation ITU-R M.1464-1, June 2003, "Characteristics of radiolocation radars, and characteristics and protection criteria for sharing studies for aeronautical radionavigation and meteorological radars in the radiodetermination service operating in the frequency band 2 700-2 900 MHz".
- [7] Commission Decision 2008/294/EC, Commission Decision of 7 April 2008 on harmonised conditions of spectrum use for the operation of mobile communication services on aircraft (MCA services) in the Community.
- [8] CEPT Report 39: Report from CEPT to the European Commission in response to the Mandate to develop least restrictive technical conditions for 2 GHz bands.
- [9] CEPT Report 016: Report from CEPT to the European Commission in response to the Mandate on Mobile Communication Services on board aircraft (MCA).